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AN INVESTIGATION INTO THE EFFECT OF VARYING WATER PRESSURE AND FLOW RATES UPON THE RELEASE OF AIRBORNE RESPIRABLE DUST BY A DOSCO MKIIB ROADHEADER EQUIPPED WITH A WATER JET ASSISTED CUTTING HEAD

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January 1986

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MICROMEDIA

ENERGY RESEARCH PROGRAM
COAL RESEARCH LABORATORIES
DIVISION REPORT ERP/CRL 86-16(IR)

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by

G.A. Haslett*, G.R. Corbett** and D.A. Young**

ABSTRACT

There are currently some 20 roadheaders equipped with a water jet assist feature operating within the western world. Five of these, some 25% of the total, are operating in the development of CBDC's new Phalen mine.

The opportunity was taken to conduct an investigation into the effects that a range of medium pressure jet assistances might have upon the production of respirable airborne d[illegible].

The roadheader selected is cu[illegible]ng a decline tunnel that is supported by heat-treated, U-shaped steel arches of internal dimensions 5.5 m width by 3.75 m height. These dimensions give an approximate excavated cross-sectional area of 17.7 m^2. The decline tunnel is being driven in the Phalen Seam. Variations in seam height and gradient resulted in a decline tunnel face of between 28% and 61% rock including siltstones, mudstones and sandstones.

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ÉTUDE DE L'EFFET DE VARIATIONS DE LA PRESSION ET DU DÉBIT D'EAU SUR LE DÉGAGEMENT DE PARTICULES INHALABLES DANS L'AIR PAR UNE MACHINE DE TRAÇAGE DOSCO MKIIB À TAILLANT AIDÉ PAR JET D'EAU

par

G.A. Haslett*, G.R. Corbett** et D.A. Young**

RÉSUMÉ

Environ 20 machines de traçage assistées par jet d'eau sont actuellement exploitées dans l'ensemble des pays occidentaux; cinq d'entre elles, soit environ 25%, sont utilisées pour l'exploitation de la nouvelle mine Phalen de la CBCD.

On a profité de l'occasion pour effectuer une étude des effets d'une gamme de pressions intermédiaires du jet d'eau sur le dégagement de poussière inhalable dans l'air.

La machine de traçage choisie perce une descenderie à trois soutenues par des cintres d'acier traité thermiquement en forme de U dont les dimensions intérieures sont 5,5 m de largeur et 3,5 m de hauteur. Ces dimensions donnent une aire d'excavation en coupe transversale d'environ 17,7 m^2. La descenderie est percée dans la veine Phalen. Les variations de la hauteur et de la pente de la veine font que le front d'attaque de la descenderie présente entre 28 et 61 % de roche dont les siltstones, des mudstones et des grès.

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INTRODUCTION

The use of medium pressure jets, up to 1035 bar (15,000 psi), to reduce the cutting forces in certain rocks has both been measured and quantified. The mechanisms that apply to the reduction of such forces remain as yet only postulated and will require further research before satisfactory theories can be defined.

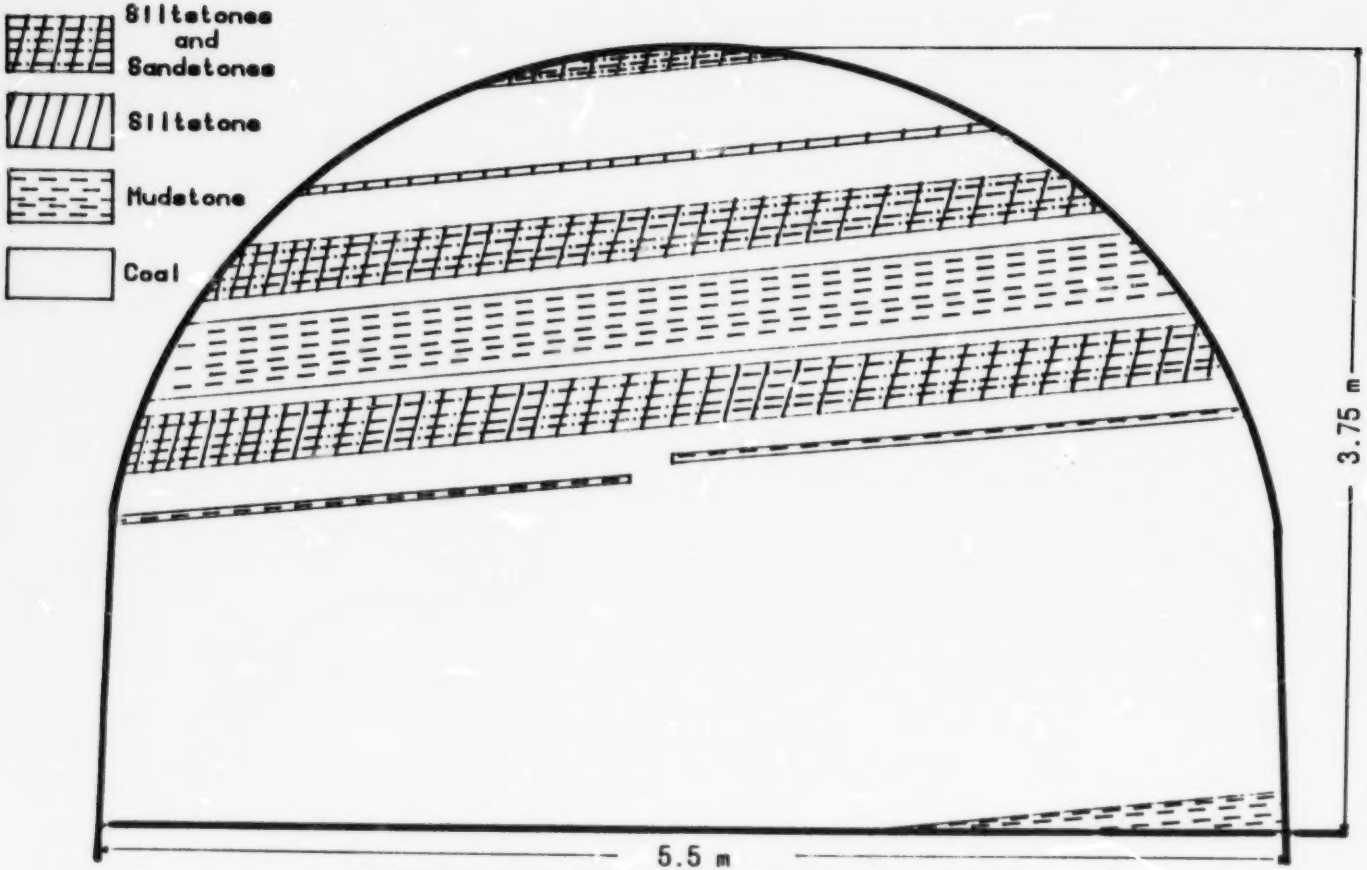
The main tunnel declines at the CBDC's new Phalen mine are being driven in a mixture of coal and soft rocks that require only low breakout forces and, at present, only predicate very marginal benefits from the application of water jet assisted cutting. These circumstances might change in the further development of the mine with more demanding conditions. There is however an opportunity provided to ascertain whether there are any benefits with the use of water pressures up to 690 bar (10,000 psi) for control of airborne respirable dust. This is a report of a cooperative trial undertaken by CBDC, CBCRL and the manufacturers of the roadheader, Dosco Overseas Engineering Ltd.

TUNNEL SITE AND CONDITIONS

The site for the trial was in the upper part of the No. 4 Tunnel decline at the Phalen mine site. At the time of the commencement of the trial, this decline had been advanced some 275 m from the surface. A further portion of this decline had already been driven ahead some 600 m from the No. 1 crosscut that intersected No. 2, 3 and 4 deeps and that drivage is continuing. The decline dips at approximately 12°C. Figure 1 illustrates a representative proximate geology at the tunnel decline face. Forcing ventilation was provided by an Engart Auxiliary Fan delivering to a flexible ducting of 0.76 m (30 in) diameter.

ROADHEADERS

The roadheader is a Dosco MKIIb machine with a cutting head diameter over the pick tips of 0.61 m (2 ft). The head comprised twenty-four



REPRESENTATIVE PROXIMATE GEOLOGY AT THE TUNNEL DECLINE FACE

Fig. 1

point attack picks, three start, one pick line, 25 mm (1 in) lacing with 20 medium pressure nozzles each of a diameter of 0.43 mm (0.017 in). Number 17, 19, 21 and 23 picks are not supplied with jet assistance. All the other picks are. The standoff distance of the jets was approximately 100 mm (4 in) at a point some 3 mm (0.12 in) ahead of the picks. Medium pressure water up to a pressure of 690 bar (10,000 psi) could be supplied to all 20 nozzles by a 5-stage Fletcher Stewart pump driven from one side of a 180 kw rated motor, the other side of which drives a hydraulic pump that powers all other services in the machine excepting the cutting head. The cutting head is powered by an independent motor of 97 kw rating and has available two cutting speeds. The lower cutting speed is 40 rpm corresponding to a pick tip peripheral velocity of 1.27 m/s (4.2 ft/sec). The higher cutting speed is 70 rpm corresponding to a pick tip peripheral velocity of 2.23 m/s (7.3 ft/sec). This higher cutting speed was used for these trials.

EQUIPMENT USED FOR MEASURING DUST

The following equipment was used to ta samples of airborne respirable dust:

i) A SIMSLIN II Dust Monitoring System

ii) Two Casella Gravimetric Samplers 113A

iii) Three or four Rothroe and Mitchell Cyclones equipped with 0.8 ^{e} Nuclepore Corp. Membra-Fil Filters

Figures 2 (a), (b) and (c) are representative of the dust sampling instrument locations during the trials. Positional adjustments were necessary so that operations were not impeded. Such arrays were kept at control points at a constant distance of 70 m (230 ft) back from the face of the tunnel decline. As the face moved forward so did the array. The start and finish of each dust sampling period was closely coordinated from the face of the tunnel decline to ensure that switching on and switching off of the samplers coincided with face cutting activity. The real-time concentration of the dust clouds were recorded by the SIMSLIN and the necessary corrections were applied to the Casella and the Cyclone results to overcome time lags between face dust generation and arrival at the control point.

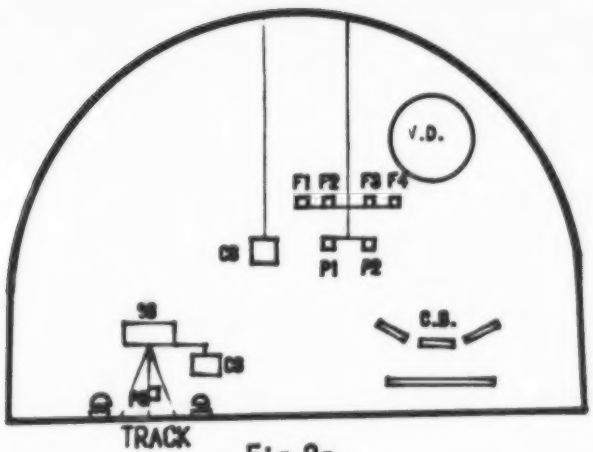


Fig 2a

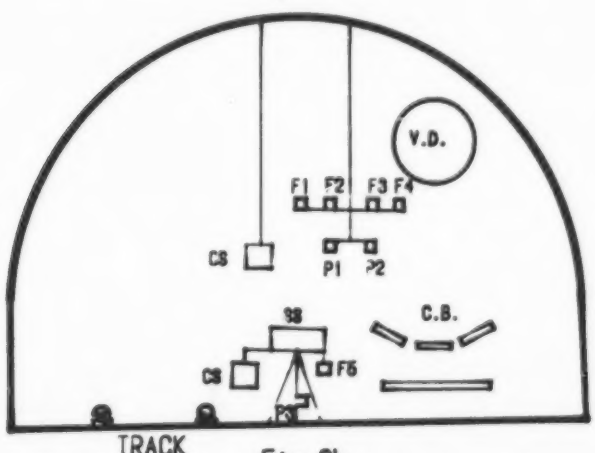


Fig 2b

KEY :

C.B = Conveyor Belt
V.D = Vent Duct
P= DuPont P 2500 A
F = Membra - Fil Filter
SS = Simslin II
CS = Casella 113 A

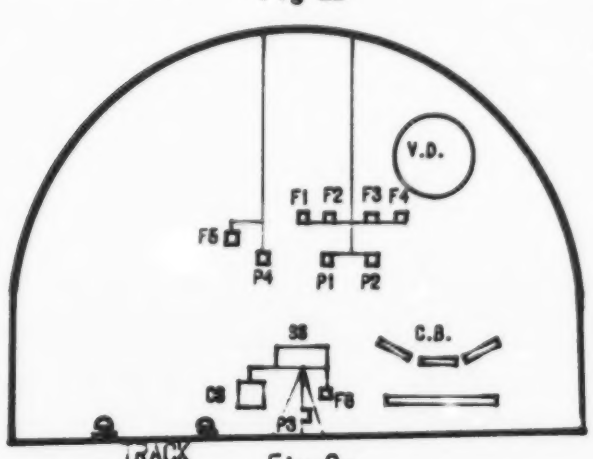


Fig 2c

Fig. 2 - Representative arrays for measuring dust

METHOD, MEASUREMENT AND RECORDS

Each trial was conducted at a constant fixed jet pressure applied to the nozzles on the cutting head of the roadheader. Before each trial commenced all of the 20 nozzles were checked. The proportions of coal/rock at the tunnel decline face were measured daily. A similar cutting pattern for each trial was closely followed. The quantities of air delivered by the ventilating duct was measured for each trial shift by a fixed pattern pitot tube point traverse within the duct.

The following information was then recorded:

a) The quantity of air flowing in the tunnel decline.

b) The volumes of coal, siltstone, mudstones and sandstones for each cut.

c) The time that medium pressure water was applied to the nozzles for each cut.

d) The cycle time of each cut.

e) The pressure supplied to the nozzles for each cut.

f) The quantity of water used for each cut.

The gravimetric respirable dust sampling instruments were started and stopped coincidentally with the face cutting activity. Time lags due to residence time within the tunnel ahead of the control point were determined by the SIMSLIN concentration time profile.

RESULTS

Table 1 (Data measured at trial site) is a record of the data that was measured and used to produce Table 2 (Data derived from measured data).

A study of the data suggests that airborne dust concentrations are dependent on the following factors:

a) The jet pressures

b) The jet energies

c) The rates of cutting

Water jet flow is controlled by pressure. Considered as an independent factor, its effect appears to be arbitrary and cannot within

Table 1 - Data measured at trial site

Date	Trial Number	Nozzle (Jet) Pressure (Bars)	Number of (Jets) Nozzles Operating	Cutting Time (mins)	Nozzle (Jets) Volume (litres)	Volume of Rock/Coal Cut m^3	Air Quantity Flowing in Tunnel Decline m^3/min	Average Respirable Airborne Dust Concentration Cyclone mg/m^3	Average Respirable Airborne Dust Concentration Casella mg/m^3
Aug 26	1	69	20	9.9	183	8.4	5.97	5.338	3.926
Aug 26	2	69	20	14.4	293	9.1	5.97	2.043	1.502
Aug 28	3	138	20	13.8	401	7.4	5.97	4.430	3.581
Aug 28	4	138	20	12.2	368	7.4	5.97	3.991	3.226
Aug 28	5	138	20	15.7	457	7.4	5.97	3.520	2.845
Aug 30	6	207	20	14.0	499	8.2	4.29	4.511	4.501
Aug 30	7	207	20	11.8	420	8.2	4.29	4.284	4.275
Aug 30	8	276	20	13.4	541	8.2	4.29	3.904	3.480
Aug 30	9	276	20	12.6	518	8.2	4.29	3.697	3.626
Aug 30	10	276	20	8.5	351	3.7	4.29	3.468	3.376
Sept 4	11	345	20	15.8	726	7.1	6.06	5.073	3.706
Sept 4	12	345	20	14.3	657	6.4	6.06	3.151	2.302
Sept 4	13	690	20	11.2	728	6.4	6.06	2.971	1.923
Sept 9	14	0	0	7.0	0	7.2	5.95	24.675	15.469

Table 2 - Data derived from measured data

Date	Trial Number	Nozzles (Jets) Flow litres/min	Nozzles (Jets) Volume litres/m^3 cut	Nozzles (Jets) Power kw/min	Nozzles (Jets) Energy kw/m^3 cut/min	Cutting Rate m^3/min	Sp.Wt. mg/m^3 cut Cyclone	Sp.Wt. mg/m^3 cut Casella
Aug 26	1	18.48	21.8	2.1	2.48	0.85	117.616	86.493
Aug 26	2	20.38	32.2	2.3	3.64	0.63	79.06	58.139
Aug 28	3	29.08	54.2	6.7	12.50	0.54	67.909	54.897
Aug 28	4	30.06	49.6	6.9	11.38	0.61	64.394	52.056
Aug 28	5	29.11	61.8	6.7	14.23	0.47	62.467	50.498
Aug 30	6	35.66	60.9	12.3	21.00	0.59	51.923	51.803
Aug 30	7	35.59	51.2	12.2	17.56	0.69	44.830	44.727
Aug 30	8	40.39	66.0	18.5	30.23	0.61	44.938	40.054
Aug 30	9	41.12	63.2	18.7	28.74	0.65	44.488	43.631
Aug 30	10	41.27	94.9	18.9	43.45	0.44	84.439	82.208
Sept 4	11	45.97	102	26.4	58.75	0.45	151.542	110.698
Sept 4	12	45.94	103	26.3	58.86	0.44	164.114	119.882
Sept 4	13	65.03	114	74.6	130.0	0.57	286.977	185.736
Sept 9	14	0	0	0	0	1.03	550.555	345.163

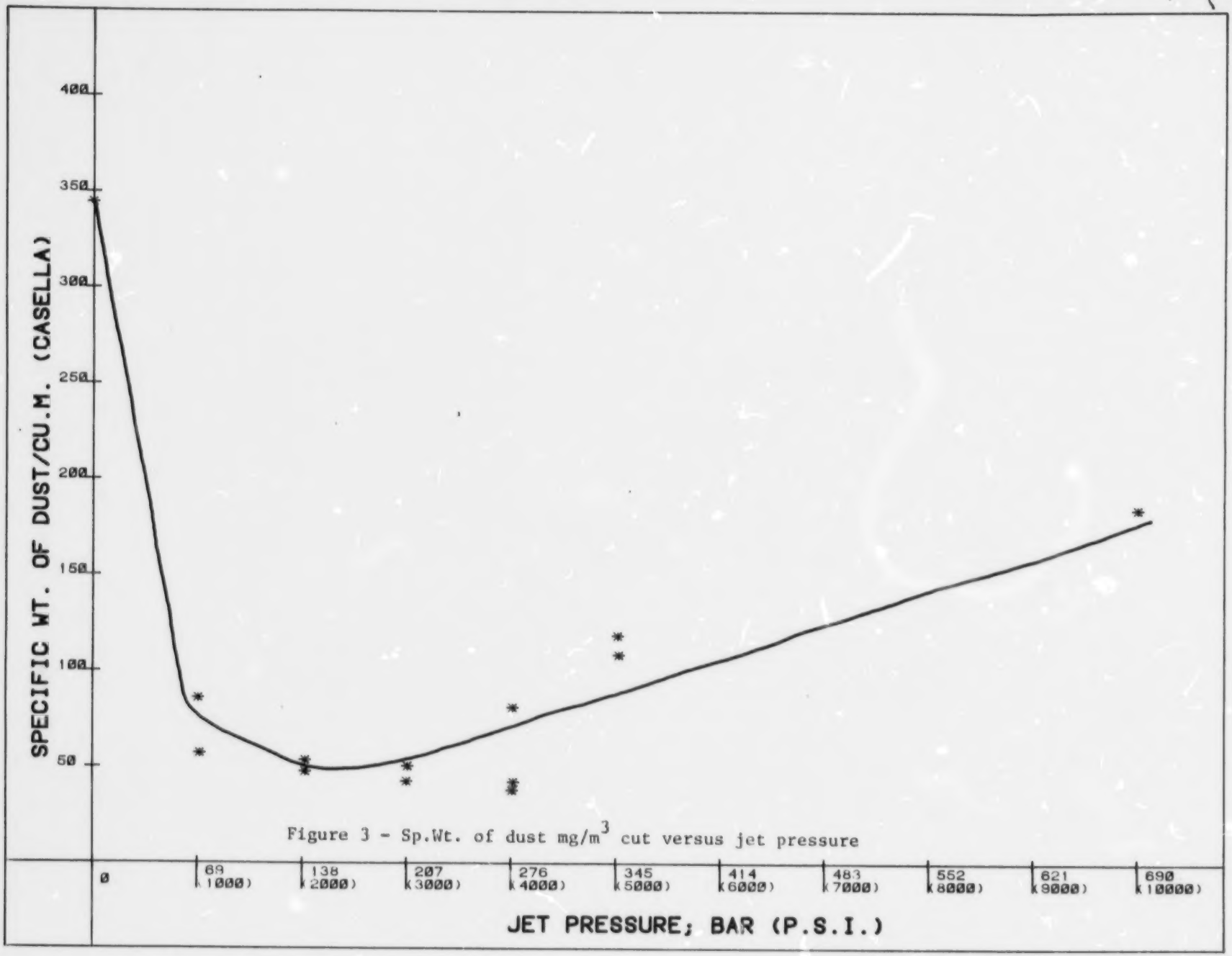


Figure 3 - Sp.Wt. of dust mg/m^3 cut versus jet pressure

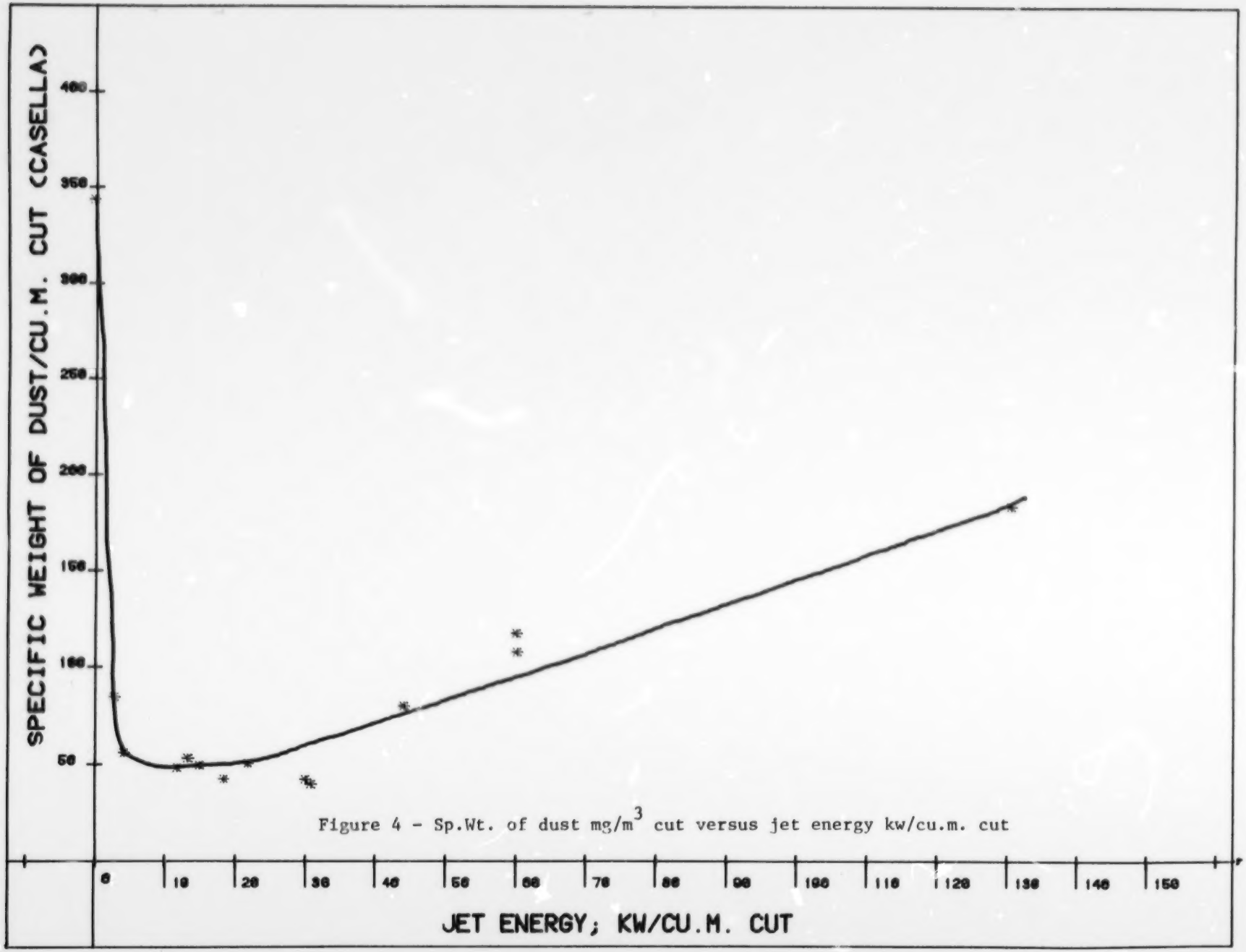


Figure 4 - Sp.Wt. of dust mg/m^3 cut versus jet energy kw/cu.m. cut

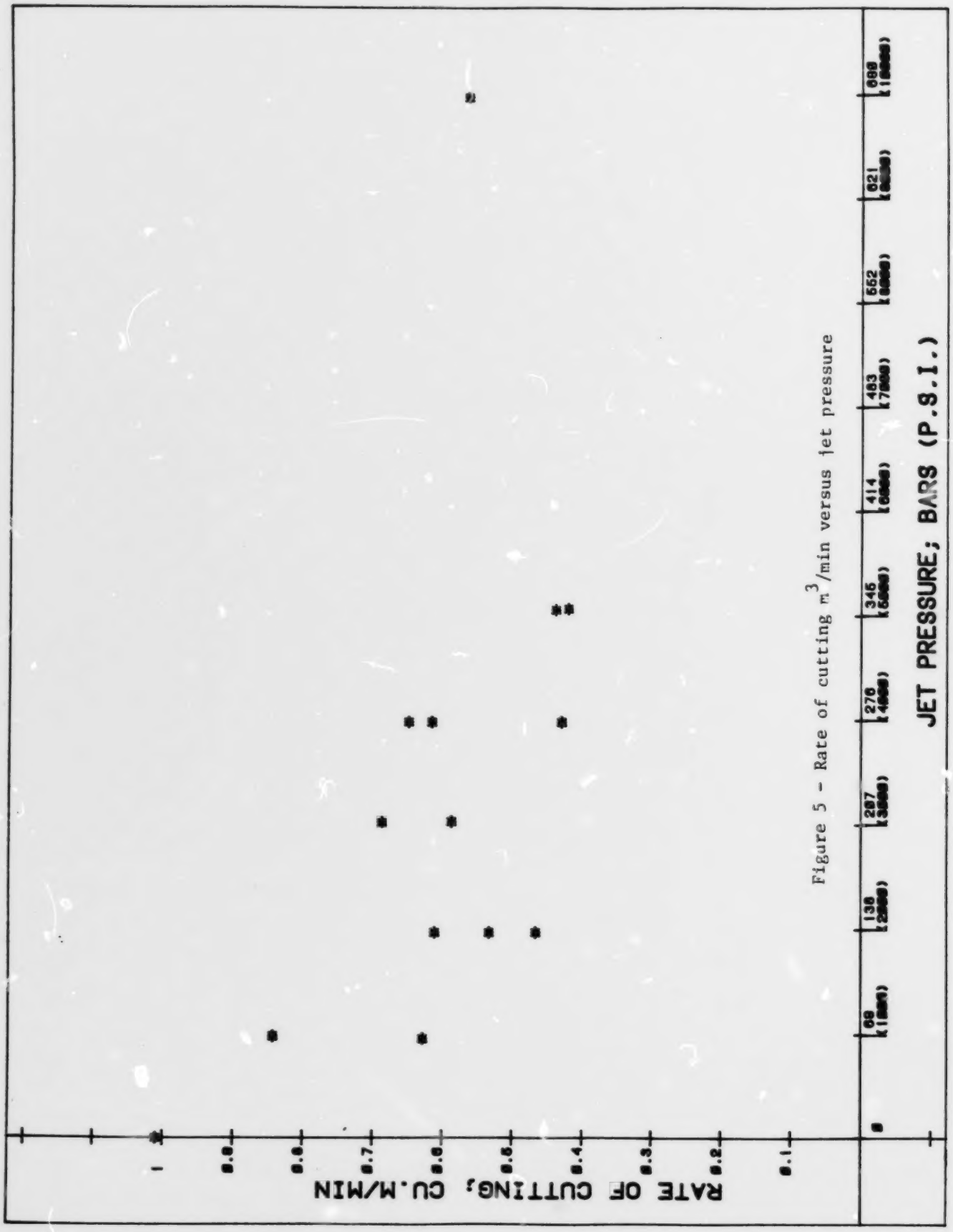


Figure 5 - Rate of cutting m^3/min versus jet pressure

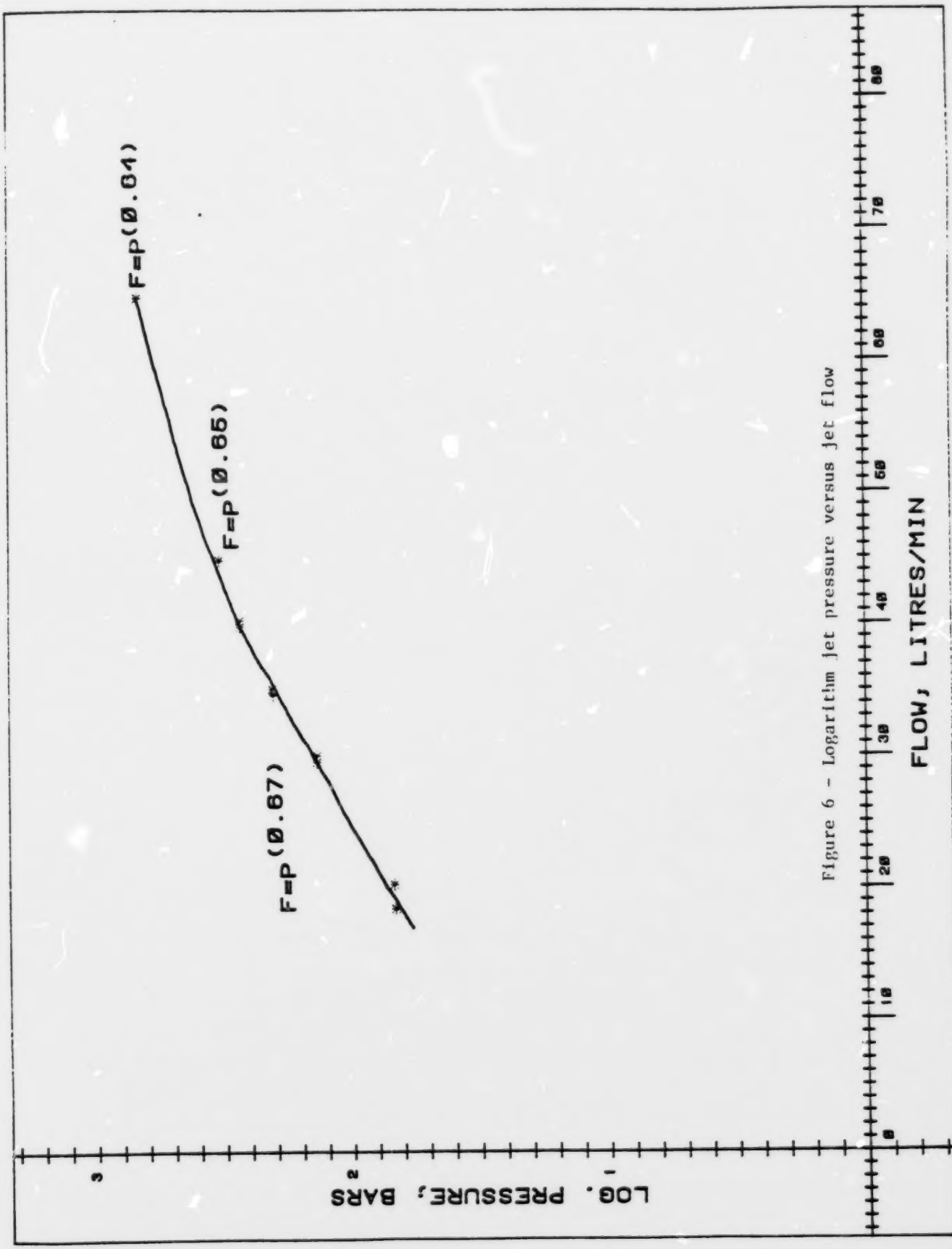


Figure 6 - Logarithm jet pressure versus jet flow

these trials be rationalised or quantified excepting when considered with pressure to produce the required jet energy.

The Casella readings were accepted as probably more accurate than the Cyclone readings which nevertheless were used as a useful check. The airborne dust concentrations were then resolved into specific weights of dust in milligrammes produced for 1 m^3 cut by the roadheader with appropriate corrections applied to account for variations in the quantities of air that were flowing past the sampling point.

The following functions were then graphically plotted:

1) Figure 3 - Sp.Wt. of Dust mg/m^3 cut versus Jet Pressure.
2) Figure 4 - Sp.Wt. of Dust mg/m^3 cut versus Jet Energy kw/cu.m. cut
3) Figure 5 - Rate of Cutting m^3/min versus Jet Pressure.
4) Figure 6 - Logarithm Jet Pressure versus Jet Flow.

1) Figure 3 - Sp.Wt. of Dust mg/m^3 cut versus Jet Pressure

This graph indicates that there is a rapid fall in the make of dust with increasing pressures from 0 until between 69 bar (1000 psi) to 138 bar (2000 psi) with an optimum pressure of approximately 155 bar (2,250 psi). Thereafter the production of dust increases steadily, almost as a linear function, to the limiting pressure of the trial which was 690 bar (10,000 psi).

2) Figure 4 - Sp.Wt. of Dust mg/m^3 cut versus Jet Energy kw/cu.m. cut

Five values of sp.wt. of dust mg/m^3 cut lie at the heel of this curve and vary within ±7%. The corresponding cutting rates have a greater variance but are within the limits of ±14.5%. Beyond and below these five points are a further three, more divergent from the curve, but with closer variances for the sp.wt. of dust mg/m^3 cut ±5.5% and also for the rates of cutting ±6.1%.

The range of jet energies supplied for the first mentioned five points are between 2.48 kw/m^3 cut and 21 kw/m^3 cut. The flows indicated for such energy levels at a fixed cutting rate of 0.6 m^3/min would be 2.86 litres/min (6.3 gal/min) and 36 litres/min (7.93 gal/min). The corresponding values as litres/m^3 cut are 47.7 (10.5 gal) for the former and 60 litres (13.2 gal) for the latter. A 3.5-fold increase in energy levels brings no real benefit in reductions of the values of sp.wt. of dust mg/m^3 cut.

The range of energies for the three further points are approximately 17.5 kw/m^3 cut - 30 kw/m^3 cut and indicate a possible reduction in the values of sp.wts. of dust mg/m^3 cut of an order of 20%.

For the three remaining points beyond on this graph at energy levels of 59 kw/m^3 cut - 130 kw/m^3 cut there are significant increases in the sp.wts. of dust mg/m^3 cut.

At a pressure of 690 bar (10,000 psi) the energy supplied by the jets represents approximately 77% of the power that the cutting head motor could supply when working at its maximum rating.

When cutting at 690 bar (10,000 psi) particles of rock and coal were projected in abundance from the face of the tunnel decline. This phenomenon suggested that the breakout forces for normal and efficient cutting were being exceeded and that the jet energy was being concentrated in a process of unnecessary comminution.

3) Figure 5 - Rate of cutting m^3/min versus Jet Pressure

Rate of cutting is not a well controlled variable. Minor variations in the approach and control of the roadheader by different operators can result in large changes in the overall effective rate of cutting for an individual test. It is, however, clear from Figure 5 that there is a reduction in rate of cutting with increasing water jet assist pressure.

Without the opportunity of running tightly controlled laboratory style experiments, this result remains largely a matter for conjecture. The reduction in the rate of cutting would be the result of reduced forces or power applied to the cutting head (water jet assist is provided by a water pump powered off the roadheader main hydraulic pump motor). The change in rate of cutting with water jet assist pressure could also indicate a competition between drag cutting and water jet cutting mechanisms. Alternatively, the reduced visibility resulting from the water jet assist pressure sprays may have led the roadheader operator to change to a more conservative method of roadheader operation.

4) Figure 6 - Logarithm Jet Pressure versus Jet Flow

It can be seen from Figure 6 that the index power of the pressure varies only by 0.03 for the complete range of pressures available with the nozzles in use on this roadheader 69 bar (1,000 psi) to 690 bar (10,000 psi).

For a nozzle size of only 0.47 mm this variation is remarkably small and suggests that a coherent and effective jet stream is available from the nozzles throughout this range.

RECOMMENDATIONS

For tunnelling within the Phalen Seam with a Dosco MKIIb roadheader an optimum pressure of 155 bar (2,250 psi) is recommended at cutting rates of approximately 0.6 m^3/min (0.78 yds^3/min).

CONCLUSION

The process of fragmentation is sensitive both to the types and quantities of energy that are applied to produce it.

It would be useful to a further understanding of the efficient processes of fragmentation and the production of airborne dust that is consequent on fragmentation to examine the total energy supplied that causes it.

This will require the measurement of all energy sources which includes in a roadheader that of the energy supplied through the cutting head. To define efficient fragmentation requires also a statement of work.

It is considered that some relationship between efficiency (rates of cutting), the total energy supplied and the production of airborne respirable dust can be established by further trials.